CLAIMS

1.   An apparatus comprising:

an oxygen sensor cell for providing an output signal in accordance with an oxygen concentration of a gas within a measuring cell;

a pump cell for adjusting an oxygen ion flow between the measuring cell and ambient air in accordance with a pump current flowing through the pump cell;

a current managing unit for varying the pump current between a first constant current and a second constant current in accordance with the output signal.

2.   An apparatus in accordance with claim 1, further comprising:

a computing device configured to determine an oxygen concentration of the gas based on a pulse width ratio of a square wave of the pump current.

3.   An apparatus in accordance with claim 2, wherein the current managing device is configured to vary the pump current by maintaining the first constant current in a first direction until a first output signal threshold is detected and maintaining the second constant current in a second direction until a second output signal threshold is detected.

4.   An apparatus in accordance with claim 3, wherein the current managing device comprises:

an analog comparator circuit configured to provide a comparator output signal based on the output of the oxygen sensor cell, the comparator output signal indicating when the first output signal threshold is reached and when the second output signal threshold is reached; and

an inverting amplifier circuit connected between the analog comparator circuit and the oxygen sensor cell, the inverting amplifier circuit configured to change the direction of the pump current in response to the comparator output signal.

5.   An apparatus in accordance with claim 4, wherein the computing device is configured to determine the pulse width ratio by:

measuring a first time period corresponding to the first pump current;

measuring a second time period corresponding to the second pump current;

determining the pulse width ratio based on the first time period and the second time period; and

determining the oxygen concentration of the gas by comparing the pulse width ratio to a pulse width ratio function for the measuring cell.

6.   An apparatus in accordance with claim 5, wherein the computing device is connected to the comparator circuit, the computing device configured to measure the first time period and the second time period based on the comparator output signal.

7.   An apparatus in accordance with claim 6, wherein the computing device is configured to determine at least some values of the pulse width ratio function by determining a pulse width ratio for free air, PWM_{AIR}, when the measuring cell is exposed to free air and the first pump current is a positive pump current and the second pump current is a negative pump current.

8.   An apparatus in accordance with claim 7, wherein the computing device is further configured to determine at least some of the values of the pulse width ratio function by determining a stoichiometric pulse width ratio, PWM_{ST}, based on a pulse width ratio for free air when the first pump current is a positive pump current and the second pump current is zero.

9.   An apparatus in accordance with claim 8, wherein the computing device establishes the second pump current by opening an analog switch connected between inverting amplifier and the pump cell in accordance with a negative current cycle.

10.   An apparatus in accordance with claim 9, wherein the oxygen sensor cell is a Nernst cell.

11.   An apparatus in accordance with claim 2, wherein the computing device is configured to determine the oxygen concentration based on a frequency of the square wave.

12.   An apparatus in accordance with claim 11, wherein the computing device is configured to apply a pressure compensation factor based on the frequency to determine the oxygen concentration.

13.   A method of measuring an oxygen concentration of a gas, the method comprising:
            receiving an output signal from an oxygen sensor cell;
            measuring an oxygen concentration within a measuring cell; and
            varying a flow of oxygen ions within the measuring chamber by varying a pump current through a pump cell controlling the flow of oxygen between a first constant pump current and a second constant pump current in response to the output signal.

14.   A method in accordance with claim 13, further comprising:

determining the oxygen concentration of the gas by comparing a pulse width ratio of the resulting square wave of the pump current to a pulse width ratio function.

15.   A method in accordance with claim 14, wherein varying the flow comprises:

directing the pump current in a positive direction at a constant magnitude until the output signal reaches an upper threshold; and

directing the pump current in a negative direction at the constant magnitude until the output signal reaches a lower threshold

16.   A method in accordance with claim 15, wherein the directing the pump current in a positive direction and directing the current in a negative direction forms an oscillating output signal having a varying pulse width ratio and a varying frequency.

17.   A method in accordance with claim 14, further comprising:

performing a calibration procedure by determining at least some factors of the pulse width function.

18.   A method in accordance with claim 17, wherein the performing the calibration procedure comprises:

exposing the oxygen sensor cell to a known gas with a known oxygen concentration; and

determining a corresponding oxygen ion flow for the constant pump current.

19.   A method in accordance with claim 18, wherein determining the corresponding oxygen ion flow for the constant pump current comprises:

determining a relationship between a Lambda coefficient of the oxygen sensor cell and the pulse width ratio.

20.   A method in accordance with claim 19, wherein determining a relationship between the Lambda coefficient of the oxygen sensor cell and the pulse width ratio comprises:

determining at least two points on a line representing the relationship between Lambda and the pulse width ratio.

21..   A method in accordance with claim 20, wherein the determining at least two points on the line representing the relationship between Lambda and the pulse width ratio comprises:

directing the pump current in the positive direction until the upper threshold

is reached;

directing no pump current until a lower threshold is reached; and

observing a calibration pulse width ratio.

5   22.   A method in accordance with claim 17, wherein the performing the calibration procedure comprises:

exposing the oxygen sensor cell to a first known gas with a known oxygen concentration;

determining a positive corresponding oxygen ion flow for the positive

10   constant pump current; and

determining a negative corresponding oxygen ion flow for the negative constant pump current.

23.   A method in accordance with claim 16, further comprising:

15   compensating for an offset of the oxygen concentration based on environmental conditions.

24.   A method in accordance with claim 23, wherein the compensating comprises adjusting a value for the oxygen concentration of the gas based on the frequency

20   of the oscillating output signal.

25.   A method in accordance with claim 24, wherein the adjusting the value for the oxygen concentration of the gas comprises:

determining an operating pump cell impedance of the pump cell;

25   applying a corresponding Lambda associated with the operating pump cell impedance.

26.   A method in accordance with claim 25, wherein the compensating comprises changing a temperature of the pump cell based on

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27.   A method in accordance with claim 22, wherein the compensating comprises changing a temperature of the pump cell based on the frequency.

28.   A method in accordance with claim 25, wherein the determining the

35   operating pump cell impedance comprises:

determining a gain of an inverting amplifier circuit directing the current, the inverting amplifier comprising an operational amplifier having an output connected to the pump cell, and an input resistor connected to the input of the operational amplifier.

29.   A method of determining an oxygen concentration of gas, the method comprising:

receiving an output signal from an oxygen sensor cell;

measuring an oxygen concentration within a measuring cell;

varying a flow of oxygen ions within the measuring chamber by applying an input voltage at a resistor connected to a negative input of an inverting amplifier to vary a pump current through a pump cell controlling the flow of oxygen between a first constant pump current and a second constant pump current in response to the output signal; and

determining the oxygen concentration based on the input voltage.

30.   A method in accordance with claim 29, wherein the determining the oxygen concentration comprises:

applying a pulse width ratio of a square wave representing the pump current to a pulse width ratio function.

31.   A method in accordance with claim 30 wherein the determining the oxygen concentration further comprises:

measuring a first time period of a positive pulse of the square wave corresponding to the first constant pump current;

measuring a second time period of a negative pulse of the square wave corresponding to the second constant pump current;

calculating the pulse width ratio by diving the difference between the first time period and the second time period by the sum of the first time period and the second time period.

32.   A method in accordance with claim 31, wherein the applying the pulse width ratio comprises calculating the oxygen concentration in accordance with the equation: $\lambda_{PRE} = P/(PWM_{AIR} - PWM_{RATIO})$, where $P = (1+PWM'_{AIR})(1- PWM_{AIR}) / (1-PWM'_{AIR})$, λ_{PRE} is the oxygen concentration, PWM_{RATIO} is the pulse width ratio, PWM_{AIR} is a pulse width ratio for free air when the second current is negative, and PWM'_{AIR} is a pulse width ratio for free air when the second current is zero.

33.   A method in accordance with claim 32, wherein applying the pulse width ratio further comprises calculating the oxygen concentration in accordance with the equation $\lambda = M^*\lambda_{PRE} + (1-M)$, where λ is the oxygen concentration when λ_{PRE} is less than one, and M is constant representing a correction factor for the measuring cell.

34.   A method of measuring a pump cell impedance of a pump cell, the method comprising:

alternating a pump current through the pump cell between a constant positive pump current and a constant negative pump current;

measuring a first voltage at an input of the pump cell at a first transition point from the constant positive pump current to constant negative pump current;

measuring a second voltage at the input of the pump cell at a second transition point from the constant negative pump current to the constant positive pump current; and

determining the pump cell impedance based on a difference between the first voltage and the second voltage.

35.   A method in accordance with claim 34, wherein the alternating the pump current comprises:

directing the constant positive pump current and the constant negative pump current from an inverting amplifier in response to a comparator output signal from an analog comparator circuit, the analog comparator circuit receiving an output signal from an oxygen sensor cell connected to the pump cell.

36.   A method in accordance with claim 35, wherein the measuring the first voltage and measuring the second voltage are in response to the comparator output signal.

37.   A method in accordance with claim 30, wherein the receiving the output signal from the oxygen sensor cell comprises receiving the output signal through a sensing resistor having a resistance and wherein the determining the pump cell impedance comprises calculating the pump cell impedance using the equation: $R_{PUMP} = R(U_{DIFF}/ Vcc)$, where R_{PUMP} is the pump cell impedance, U_{DIFF} is the difference between the first voltage and the second voltage and Vcc is the supply voltage to the analog comparator circuit.

38.   A method of determining an Nernst cell impedance of a Nernst cell producing an output signal based on an oxygen concentration within a measuring cell and connected within an oxygen concentration measuring circuit comprising an operational amplifier for varying a pump current through a pump circuit controlling an oxygen ion flow through the measuring cell; an analog comparator circuit providing an input voltage at a inverting input resistor connected to an inverting input of the operational amplifier in response to the output signal received through a sensing resistor, the method comprising:

calculating a peak-peak voltage as the difference between a sample voltage at a low-high transition and a high-low transition of the analog comparator circuit; and

determining the Nernst cell impedance based on a value of the sensing resistor and the peak-peak voltage.

39.   A hand-held diagnostic device comprising:

an oxygen sensor cell for providing an output signal in accordance with an oxygen concentration of a gas within a measuring cell;

a pump cell for adjusting a oxygen ion flow between the measuring cell and ambient air in accordance with a pump current flowing through the pump cell;

a current managing unit for varying the pump current between a first constant current and a second constant current in accordance with the output signal;

a computing device configured to determine an oxygen concentration of the gas based on a pulse width ratio of a square wave of the pump current; and

a user interface connected to the computing device.

40.   A device in accordance with claim 39, wherein the user interface is a display.

41.   A device in accordance with claim 40, wherein the user interface further comprises a button.